PATENT SPECIFICATION

(11) 1 426 617

1 426 617

(21) Application No. 27669/73 (22) Filed 11 June 1973
(31) Convention Application No. 7 684/72 (32) Filed 12 June 1972 in
(33) Sweden (SW)
(44) Complete Specification published 3 March 1976
(51) INT. CL.[2] H01B 13/06
(52) Index at acceptance
H1A 2E2A 2E3B 2E3D1 2E3D2 2E4C 2E5 4B 5
(19)

(72) Inventors DICK JOHAN RUDOLFSSON
LARS-GÖRAN VIRSBERG

(54) METHOD OF MANUFACTURING INSULATED ELECTRICAL CONDUCTORS

(71) We, ALLMÄNNA SVENSKA ELEKTRISKA AKTIEBOLAGET, a Swedish Company, of Västerås, Sweden, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following Statement: —

It is known to surround an electrical conductor with a shrinkage tube, so that it is possible to effect shrinkage of the shrinkage tube on to the conductor by placing the conductor in a furnace. It has also been proposed to effect shrinkage by moving the conductor through a hot air zone, the direction of movement substantially coinciding with the longitudinal direction of the shrinkage tube. However, it has proved difficult to effect a uniform shrinkage of the shrinkage tube when using said methods, especially in the case of thick conductors, and non-uniform shrinkage easily results in the formation of air pockets, which are not acceptable from the corona point of view, and also unfavourable variations in the wall thickness of the finished insulation.

The drawbacks of the previously used methods are avoided by the method of the present invention, which makes it possible to manufacture an electrical conductor having insulation which is completely free from voids and, accordingly, free from corona. The invention also makes it possible to employ a shrinkage tube for insulating a conductor for a considerably higher voltage than has previously been possible.

According to the invention, a method of manufacturing an insulated electrical conductor, for example a bar for switchgear or a coil for an electric machine, in which a conductor or a bundle of individual conductors is surrounded by a shrinkage tube in unshrunk condition and the shrinkage tube is caused to shrink by heating to produce close contact between the shrunk shrinkage tube and the conductor or conductor bundle, is characterised in that shrinkage is effected by bringing the shrinkage tube, which surrounds the conductor or conductor bundle, into contact with molten metal or molten metal alloy which has a temperature required for effecting the shrinkage. In order to simplify the ensuing description the term "conductor" will be used hereinafter to include a single conductor or a bundle of individual conductors. Furthermore, the term "metal" will be used to include both metal and metal alloy.

Preferably the conductor with the surrounding shrinkage tube is brought into contact with the molten metal by being immersed in a bath of the molten metal. In this case it is advantageous if the conductor is positioned so that the central axis of the shrinkage tube is inclined at a certain angle to the horizontal plane, preferably so that the axis of the shrinkage tube is substantially vertical. By positioning the conductor in this way, it is made sure that the air inside the shrinkage tube is allowed to depart freely upwards, while the conductor is progressively immersed in the bath and the shrinkage tube shrinks and provides close contact with the conductor.

In principle it is possible to effect the shrinkage otherwise than by immersing the conductor in a bath of the metal. It is possible, for example, to spray or pour the metal on to the shrinkage tube, and in this case the metal is suitably supplied progressively from one end of the conductor to the other end.

A likely explanation of the favourable results obtained by the method according to the present invention is that the good thermal contact between the shrinkage tube and the metal and the good thermal con-

ductivity of the metal give a quick and uniform supply of heat to the shrinkage tube, so that the tube becomes efficiently heated and its shrinkage is completed simultaneously throughout the entire cross-section of the tube. The supply of heat is so efficient that is overcomes the cooling effect arising from the conductor, which is prejudicial to the achievement of rapid shrinkage. If an efficient supply of external heat is not ensured, the shrinkage may easily become uneven, as parts of the shrinkage tube achieve heat-conducting contact with the conductor at different times. As soon as a part of a shrinkage tube is brought into heat-conducting contact with the conductor in previously known methods, an interruption in or a reduction of the shrinkage occurs owing to the lower temperature of the conductor, whereas the shrinkage process still continues unimpededly in other parts of the shrinkage tube. Parts of the shrinkage tube which are situated at varying distances from the conductor at the start can thus undergo varying degrees of shrinkage, which results in irregularities in the thickness of the shrinkage tube on the final product.

The metal used in the method of the invention must of course have a relatively liw melting point, in order that the material of the shrinkage tube and any other electrical insulating material in the conductor should not be broken down thermally when it is brought into contact with the molten metal. The melting temperature of the metal should not exceed 500°C. So far as the lower limit of the melting temperature of the metal is concerned, this must of course be at least as high as the temperature which is required to effect shrinkage of the shrinkage tube and preferably at least 50°C above this temperature. A suitable temperature of the metal when using a commercially available shrinkage tube of conventional type is within the range 100-400°C. Examples of metals having melting temperatures which are suitable for the method of the invention are Wood's metal (melting point 70°C), an alloy consisting of 53 *per cent* by weight of bismuth, 32 *per cent* by weight of lead and 15 *per cent* by weight of tin (melting point 96°C), an alloy consisting of 62 *per cent* by weight of tin and 38 *per cent* by weight of lead (melting point 183°C), tin (melting point 232°C), bismuth (melting point 271°C), cadmium (melting point 321°C) and lead (melting point 327°C).

The length of time during which a portion of the shrinkage tube has to be in contact with the metal melt in order to effect shrinkage depends on the temperature of the melt and may in practice amount to a few seconds.

As examples of materials for the shrinkage tube may be mentioned silicone rubber, cross-linked polyolefin, polyvinyl chloride, polyvinyl fluoride, polyvinylidene fluoride, polyethylene glycol terephthalate, polytetrafluoroethylene, modified neoprene and modified fluoro rubber.

In order to obtain freedom from voids even if the conductor has a very uneven surface, for example if it has deep pockets in its surface, which can particularly be the case if the conductor consists of a bundle of conductors, it may be advantageous to apply an electrically insulating material between the conductor and the shrinkage tube, said material being soft or liquid at the temperature at which shrinkage is effected. This insulating material, which acts as a fill-in material, is pressed into any pockets or other uneven parts during the shrinking process, thus achieving with greater certainty formation of an insulation which is free from voids. As examples of such an insulating material may be mentioned thermoplastics material, for example polyethylene (not cross-linked), asphalt, waxes and gelatinous substances. An appropriate manner of applying this material is to apply it on the inside of the shrinkage tube in connection with the manufacture of the shrinkage tube. It is also possible to apply it, for example, as a coating on the conductor.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which

Figure 1 is a side view of a single turn coil,

Figure 2 is a side view of a multiturn coil,

Figure 3 is a side view of a switchgear bar,

Figure 4 is a cross-sectional view, on an enlarged scale, of a conductor of a coil according to Figure 1 or 2, with a shrinkage tube applied in unshrunk condition,

Figure 5 is a view similar to Figure 4 but showing the situation after shinkage of the shrinkage tube has been effected,

Figure 6 is a cross-sectional view, on an enlarged scale, of the bar of Figure 3 with a shrinkage tube applied in unshrunk condition,

Figure 7 is a view similar to Figure 6 but showing the situation after shrinkage of the shrinkage tube, and

Figure 8 is a schematic section view of a means for carrying out the method according to the invention.

The coil shown in Figure 1 has straight parts 10 and 11, intended to be placed in the slots of an electrical machine, and a curved end part 12 which will be outside the slots. The coil is provided with an in-

sulation consisting of a shrinkage tube 13. The terminals of the coil are designated 14 and 15. In unshrunk condition the shrinkage tube may be fitted over the conductor bundle of the coil — said bundle consisting of several individual conductors arranged cose together — from one end of the conductor bundle.

In a similar manner, the coil shown in Figure 2 has straight slot parts 16 and 17 intended to be placed in the lots of an electrical machine, and curved end parts 18 and 19 which are outside the slots. The coil is provided with an insulation consisting of a shrinkage tube 13. The terminals of the coils are designated 20 and 21. The conductor bundle of the coil consists of several turns of one single, coherent insulated conductor. In unshrunk condition the shrinkage tube may be applied around all turns of the conductor bundle by feeding the turns of the conductor bundle successively into the shrinkage tube in a manner described in British Patent Specification No. 1 330 427. One tube end is arranged to overhang the other at 37.

The bar shown in Figure 3, which consists of one single solid conductor, has a central part 22, insulated with a shrinkage tube 23, and connecting parts 24 and 25. In unshrunk condition the shrinkage tube may be fitted over the conductor from one end.

As is clear from Figures 4 and 5, the conductor bundle 26 in the coils according to Figures 1 and 2 consists of several conductors 27 arranged close to each other, each one being provided with insulation 28. The insulation may, for example, consist of a wrapping of glass yarn which has been impregnated with a binder, for example an epoxy resin, an alkyd resin, a phenolic resin or the like, which has then been cured, or of a wrapping of mica strip or of simply a varnish layer of a type which is normally used when enamelling wire for electrical conductor purposes, for example a terephthalic acid alkyd, a polyester imide, a polyimide or a silicone. The shrinkage tube 13, which consists of silicone rubber (for example Flexible Modified Silicone Elastomer from Electronized Chemicals Corp, USA), is provided on the inside with a layer 29 of an electrically insulating material which is soft at the temperature at which shrinkage is effected. This material consists, in the exemplified case, of an asphalt having a softening temperature of 150°C.

As will be seen from Figure 4, there is a relatively large space 30 between the conductor bundle 26 and the shrinkage tube 13 before shrinkage. After the shrinking process the shrinkage tube is completely fitted to the shape of the conductor bundle, as is clear from Figure 5, and part of the layer 29 has remained in pockets and similar irregular spots at the surface of the conductor bundle.

As is clear from Figure 6 the bar shown in Figure 3 has one single solid conductor 31. In the exemplified case the conductor has no other insulation than the shrinkage tube 23. The space between the shrinkage tube and the conductor prior to shrinkage is designated 33. After shrinkage the shrinkage tube is completely fitted to the shape of the conductor, as is clear from Figure 7. The shrinkage tube may, for example, consist of cross-linked polyolefin (for example "CRN" from Raychem Corp. USA).

Figure 8 illustrates how to carry out the method of the invention in the manufacture of a coil according to Figure 1. The coil is lowered with its end part 12 first and with the straight parts 10 and 11 substantially vertical into a melt 34 of tin, the temperature of which is 240°C. The temperature which is required to effect shrinkage is in this case, using the exemplified shrinkage tube of silicone rubber, around 175°C. The coil is lowered into the melt at a speed of 5 cm/sec. As soon as part of the shrinkage tube has made contact with the metal melt, it shrinks so that a cross-section according to Figure 5 is obtained. New parts of the tube are then shrunk as they are inserted into the melt. During this progressive shrinking process the air contained in the tube is pressed out and the layer 29 fills up any existing pockets. The application of the tube is finished when the two open ends 35 and 36 of the tube have been lowered to a level immediately above the level of the molten tin.

The coil according to Figure 2 may be made in a similar way, in which case the end part 18 is first immersed into the melt.

In the manufacture of a conductor according to Figure 3, the lower end 38 of the tube 23 is first tightened against the conductor for example by means of a separate shrinking step using hot air or with a clamp, before the conductor with its end 24 lowermost is progressively immersed into the melt in order to shrink the tube and thus achieve a cross-section according to Figure 7.

In order to prevent the metal from adhering to the surface of the shrinkage tube, it may be suitable in some cases to coat the surface of the shrinkage tube before the contact with the metal melt with a suitable release agent, for example a silicone grease.

WHAT WE CLAIM IS: —

1. A method of manufacturing an insulated electrical conductor, in which a conductor (as hereinbefore defined) is sur-

rounded by a shrinkage tube in unshrunk condition and the shrinkage tube is caused to shrink by heating to produce close contact between the shrunk shrinkage tube and the conductor, characterised in that shrinkage is effected by bringing the shrinkage tube, which surrounds the conductor, into contact with molten metal (as hereinbefore defined) which has a temperature required for effecting the shrinkage.

2. A method according to claim 1, in which the conductor with the surrounding shrinkage tube is brought into contact with the molten metal by being immersed in a bath of the molten metal.

3. A method according to claim 2, in which the conductor when being immersed into the metal bath is positioned so that the central axis of the shrinkage tube is inclined at a certain angle to the horizontal plane.

4. A method according to claim 3, in which the central axis of the shrinkage tube is substantially vertical.

5. A method according to any of the preceding claims, in which electrically insulating material is arranged between the conductor and the shrinkage tube, said material being soft or liquid at the temperature at which shrinkage is effected to fill up any voids in the insulated conductor.

6. A method of manufacturing an insulated electrical conductor substantially as herein described with reference to, and as illustrated in, Figure 8 of the accompanying drawing.

7. An insulated electrical conductor when made by the method claimed in any preceding claim.

J. Y. & G. W. JOHNSON

Furnival House,
14-18, High Holborn,
London, WC1V 6DE.

Chartered Patent Agents,

Agents for the Applicants.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1976. Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1426617 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

Fig.1

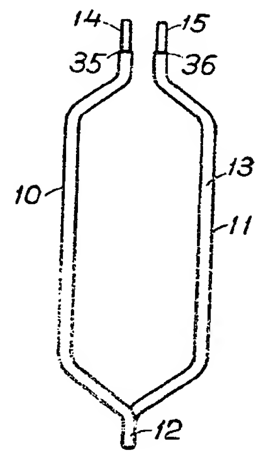

Fig.2

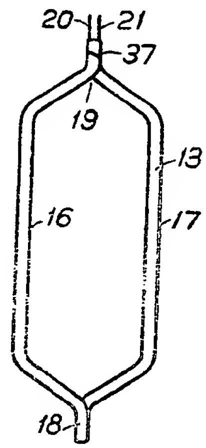

Fig.3

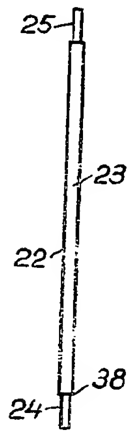

Fig.4

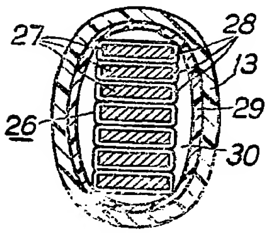

Fig.6

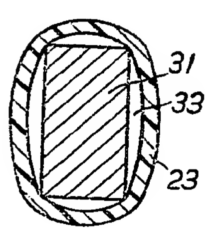

Fig.8

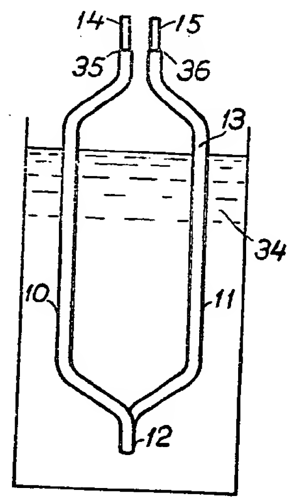

Fig.5

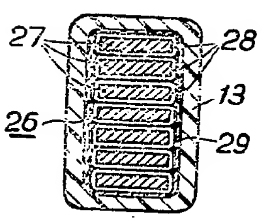

Fig.7